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Chunkwood Roads

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Chunkwood Roads

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Chunkwood Roads

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Contents

Introduction

The concept of chunking and chunkwood was introduced by USDA Forest Service researchers in the mid-1970's to reduce small, unmerchantable trees and forest residues into elongated particles. These "fingerlings" were later to be converted into long, thin flakes for flakeboard. Though originally developed for use as a raw material for the composite wood flake products industry and for energy production, it became apparent to researchers at the Forest Service's Forestry Sciences Laboratory in Houghton, Michigan, that chunkwood had potential as a roadbuilding material. Chunkwood may be an alternative where rock or gravel suitable for fill or subgrade construction is unavailable within economic haul distances. Chunkwood exhibits relatively high porosity and low bulk density, which make it desirable for embankment and subgrade construction, especially where adjacent and underlying soils are wet and weak. Wood is not as durable as mineral aggregates, but this may be an advantage when building temporary roads.

In 1987 the USDA Forest Service began investigating the use of chunkwood as an alternate material for building low-volume forest roads. The initial effort was a combined research and demonstration program involving the Eastern Region (9) Chequamegon National Forest, the North Central Forest Experiment Station Houghton Forestry Sciences Laboratory, Michigan Technological University, and the Missoula Technology and Development Center (MTDC).

The Forest Service designed and built two research and demonstration prototype wood chunking machines. The original, built at the Houghton Forestry Sciences Laboratory (Figure 1), was a stationary laboratory model that was later converted to a field unit. The log or tree was fed into a cutter wheel with blades and these blades cut off a chunk of wood from the end of the log (Figure 2). A larger capacity field prototype was later built at the Missoula Technology and Development Center (Figure 3). Both machines were used on various projects in the chunkwood roads research and demonstration effort.

This report documents the procedures and results of that effort.

Figure 1.–Original laboratory model of the wood chunker (NCES, Houghton, Michigan).

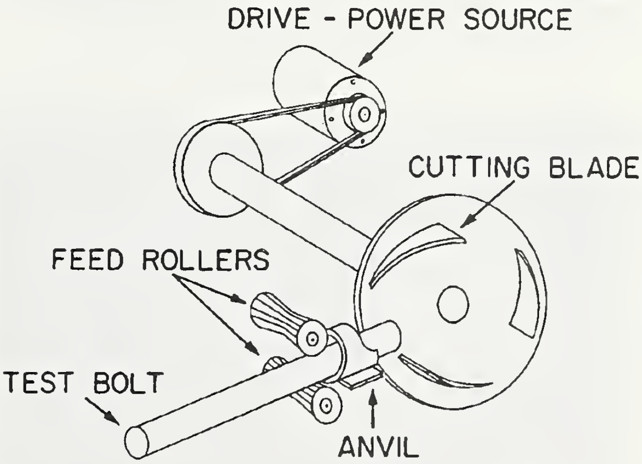

Figure 2.–Wood is fed into cutting blades and chunks are cut off.

Figure 3.–MTDC wood chunker (modified Morback Model 20 Wood Chipper).

Chunkwood Characteristics

Chunkwood is a wood fragment produced from trees or logging residues by a wood chunk machine. Although chunkwood fragments can vary widely in size, a typical chunk is about the size of a fist (Figure 4). Chunkwood particles interlock to form a relatively stable matrix, while wood chips tend to layer and easily slide over one another. Chunkwood is very permeable and water readily flows through it. Wood chips also are very permeable to water compared to most subgrade materials but are less permeable than chunkwood. Chunkwood may be generated from right-of-way clearing and unmerchantable trees or from logging residues from adjacent forests.

Figure 4.–Wood chunks.

Chunkwood can be an alternate or supplemental roadbuilding material. Some of the advantages of chunkwood are: Reduced roadbuilding costs; conservation of finite gravel resources; elimination of unsightly gravel pits and the need to restore them to an environmentally acceptable condition. It is excellent lightweight fill (about one-fifth the weight of gravel); has high water permeability (water flow through chunkwood much faster than through sand or gravel); is biodegradable, has limited life; and creates no dust from traffic.

Chunkwood Properties

Chunkwood is a compressible material with following properties:

Gradation:

Sieve Size	Percent Passing
4 inch (100 mm)	90-95
2 inch (50 mm)	40-65
1 inch (25 mm)	15-30
0.5 inch (12.5 mm)	0-10

Triaxial Strength:

C =	2 psi (13.8 kpa)
Phi (ϕ) =	37 degrees
Poisson's Ratio =	0.3
Permeability = (all directions)	20 ft/min (6.1 m/min)

Moist Unit Weight:

Field – 27-51 pounds/cubic foot (433-816 kg/m^3)
average–40 pounds/cubic foot (640 kg/m^3)

Lab – 15-21 pounds/cubic foot (240-336 kg/m^3)

Volume Reduction:

This is the ratio of loose volume of material to the volume in place and compacted.

Field – 20 to 50 percent volume reduction

Lab – 20 percent volume reduction

Road Construction With Wood

The Forest Service builds about 2,000 miles (3,200 km) and reconstructs about 7,000 miles (11,200 km) of forest roads annually. Finding cheaper or better ways to do this without compromising the forest environment is a high priority. The Agency currently maintains about 360,000 miles (576,000 km) of forest roads. Approximately 75 percent of Forest Service roads are classed as low-volume/local.

Wood has long been used for road construction. Perhaps the most familiar application is in decking and structure of wooden bridges. It is often uses for temporary or emergency roads. Especially in swamps, corduroy roads have been built with logs placed adjacent and parallel to each other, across the direction of travel. Wooden blocks have paved streets (Ritter and Paquette 1960). Wood fibers and paper mill sludge have been used for erosion control and road surface stabilization. However, the use of wood sawdust, chips, or chunks for road embankments, subgrades, or surfaces is of relatively recent origin.

Nelson and Allen (1974) described stabilization of landslides along State Route 101 near Cosmopolis, Washington, in the early 1970's. They documented that timber companies have used sawdust for many years as lightweight fill material to reclaim peat and swamps. They also reported that the city of Aberdeen, Washington, used sawdust mixed with quarry rock as a base material for many of their city streets, that the British Columbia Department of Highways used sawdust to traverse a peat deposit when constructing their Burnaby Freeway, and that, in Norway, sawdust was used as fill on a road built over 30 feet (9.1 m) of peat where severe settlements had occurred.

Based largely on the Washington State Highway Department experience, John Steward (1977), Region 6 engineer, developed tentative guidelines for designing sawdust fills for Forest Service roads.

Dale Petersen and other Forest Service engineers (1981) reported on slide areas stabilized with sawdust and bark chips on the Mt. Baker-Snoqualmie National Forests in Region 6.

A Low-volume Local Road is:

- Normally single-lane and constructed of soil or gravel.
- Designed for slow, heavy traffic.
- Subjected to low traffic volumes, generally less than 100 vehicles per day.
- Generally considered to have low construction standards.
- Often a terminal facility used on an intermittent basis for resource management and closed to use between entries.

One of the goals of this project is the widespread application of chunkwood roadbuilding technology to:

- Create new roadbuilding technologies for low-volume/local roads.
- Provide an alternate roadbuilding material that is lightweight and permeable.
- Minimize road costs.
- Conserve finite gravel supplies.
- Reduce environmental impacts.
- Reduce waste and develop uses for unmerchantable trees and residues.
- Inform other potential users to maximize benefits.
- Create biodegradable roads.

Chunkwood is appropriate in a range of roadbuilding situations such as:

- Swamps and muskeg.
- Wet clay.
- Sugar sand.
- Mud holes.
- Dust control.
- Soil stabilization.

Some roads were built entirely of chunkwood; some were built by combining chunkwood with sand, gravel, aggregate, and geotextiles.

In 1984, the WO assigned MTDC the task of constructing an evaluating the chunkwood machine to determine its usefulness for achieving Forest Service goals and, if appropriate, to establish a market for chunkwood roadbuilding technology.

MTDC Chunkwood Machine

The chunkwood field prototype was built by MTDC engineers in 1984. The MTDC chunkwood machine (Figure 3} is similar to a whole-tree chipper in it's construction and operation. However, the chunker has a different cutting head that produces larger wood particles. Because of this feature, the larger wood particles are moved from the cutter to a truck with a belt-type conveyor instead of throwing them into a truck, as would be the case with the whole-tree chipper (Figure 5).

The MTDC chunker was fabricated from a Morbark Model 20 whole-tree chipper. The original cutter head and feed roller assembly were replaced with the prototype chunker cutter unit and a revised feed system. The undercarriage (axles, brakes, wheels, frames, etc.) engine, hydraulics for the feed rollers, the slide boom loader, cab, and the control panel are all factory equipment

Figure 5.–Chunks loaded with conveyor instead of being blown into transport as is don with conventional chippers.

Machine Specifications

The chunkwood machine is trailer mounted:

Total machine weight ....32,000 lb (14,545 kg)
Tongue weight ....8,000 lb (3,636 kg)

Overall dimensions:

Length ....24 ft (7.3 m)
Width ....8.5 ft (2.6 m)
Height (to top of cab).............13 ft, 6 in (4.1 m)
Height in Transport mode.......11 ft, 9 in (3.6 m)
(with cab removed)

Machine is highway legal with government plates, brake lights, and air-over hydraulic brakes.

The chunker machine has a 2-1/2 inch (6.4 cm) towing ring attached to the tongue. It can be moved or towed with a 4.5-ton semi-tractor or 4.5-ton tandem-axle dump truck that has a 2-1/2-inch (6.4 cm) pintle hitch mounted to it.

The machine can utilize a maximum tree size of 12 inches (30 cm) in diameter. The optimum size of material for this unit would be 8 to 10 inch (20 to 25 cm) diameter green, whole trees. Softwoods are more successfully processed than hardwoods and green material is better than dry, seasoned material. Because the machine has a slide boom loader, a *hot deck* system with skidders feeding the machine works better than a *cold deck* system where the material is stockpiled and has to be pulled from a deck with the loader.

The loader has a 20-foot (6.1 m) reach 12 feet (3.7 m) in front of the feed system), It can pull material from a deck not higher than 6 feet (1.8 m).

Production rates for the chunker machine depend on setup configuration and material being chunked. Some rough estimated rates are:

Dry material skidded to chunker— 8 to 10 tons/hr (7.3 to 9.1 tons/hr) or 27 to 33 cu yd/ hr (20 to 25 m^3/hr)

Green material skidded to chunker and most trees in 8- to 9-inch (20 to 23 cm) diameter range—20 tons/hr (18.1 tons/hr)

Machine Configuration and Setup

Selecting the proper chunking site can improve the production rate. The machine should be located so the trucks hauling the chunkwood can easily be positioned under the loading conveyor. Because of the slide boom loader, the chunker works best if the material can be brought to the machine with a skidder as it is being chunked. The trees should be brought to the machine with stems aligned with the centerline of the feed system and the ends placed within 10 feet (3 m) of the feed rollers (Figure 6). The bunches or grapple loads should not be piled so high that the material has to be pulled down into the cutting head. The machine works better if the weight of the material fed into the cutter wheel rests slightly on the lower feed wheel. This can be adjusted by slightly raising or lowering the front of the machine with the stabilizer cylinders. Figures 7 and 8 show ideal configuration layouts.

Once a site is selected, the machine is moved in, leveled, the inclined conveyor lowered into operating position (Figure 9), and the side extensions are attached to the inclined conveyor. The portable loading conveyor is then positioned and its' towing hitches removed. After positioning the chunker and portable conveyor, the conveyor hydraulic connections are coupled. Proper clearance between the chunker conveyor and the portable conveyors is essential and the belts must be able to move freely.

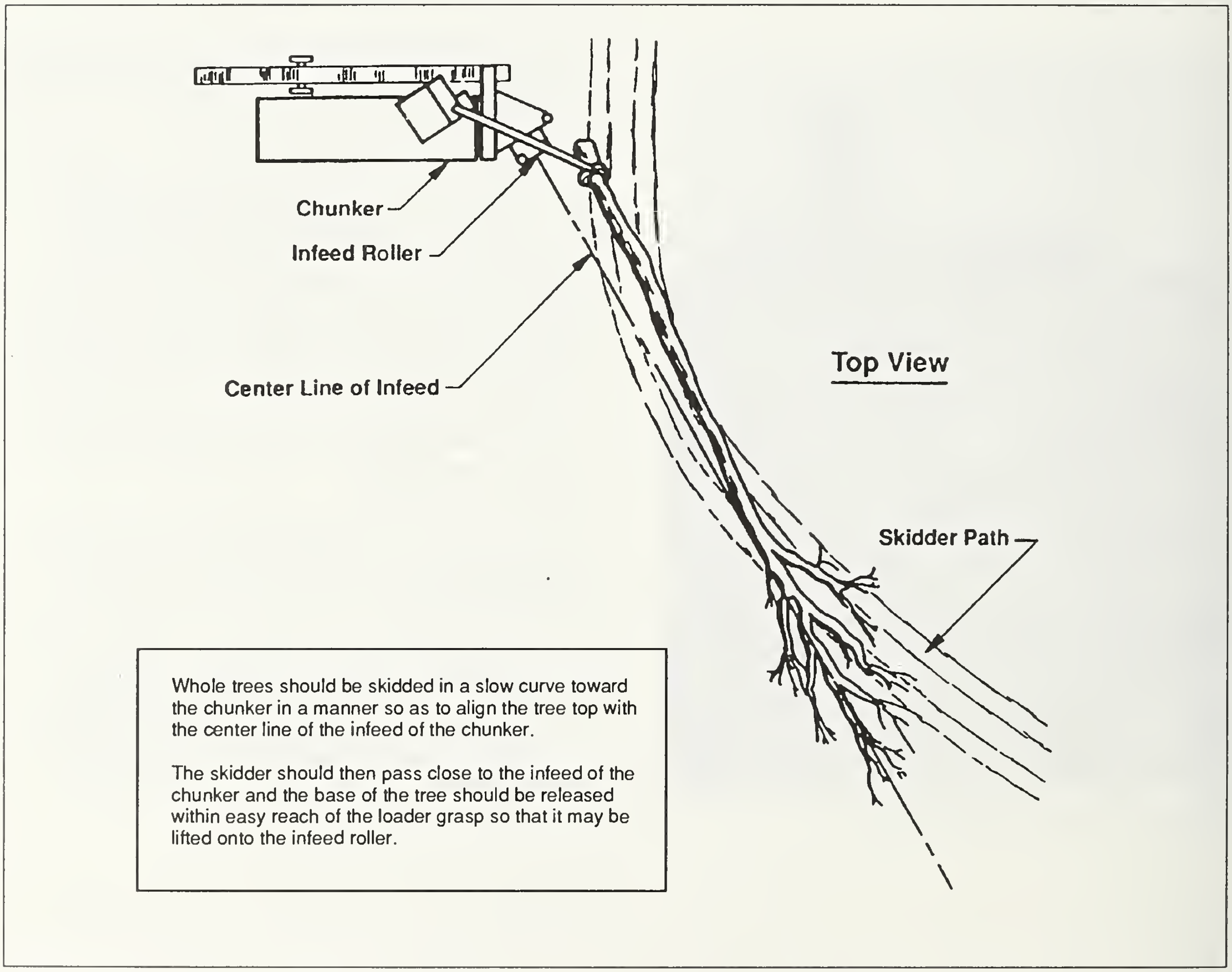

Figure 6.–Operational layout of material brought to chunker.

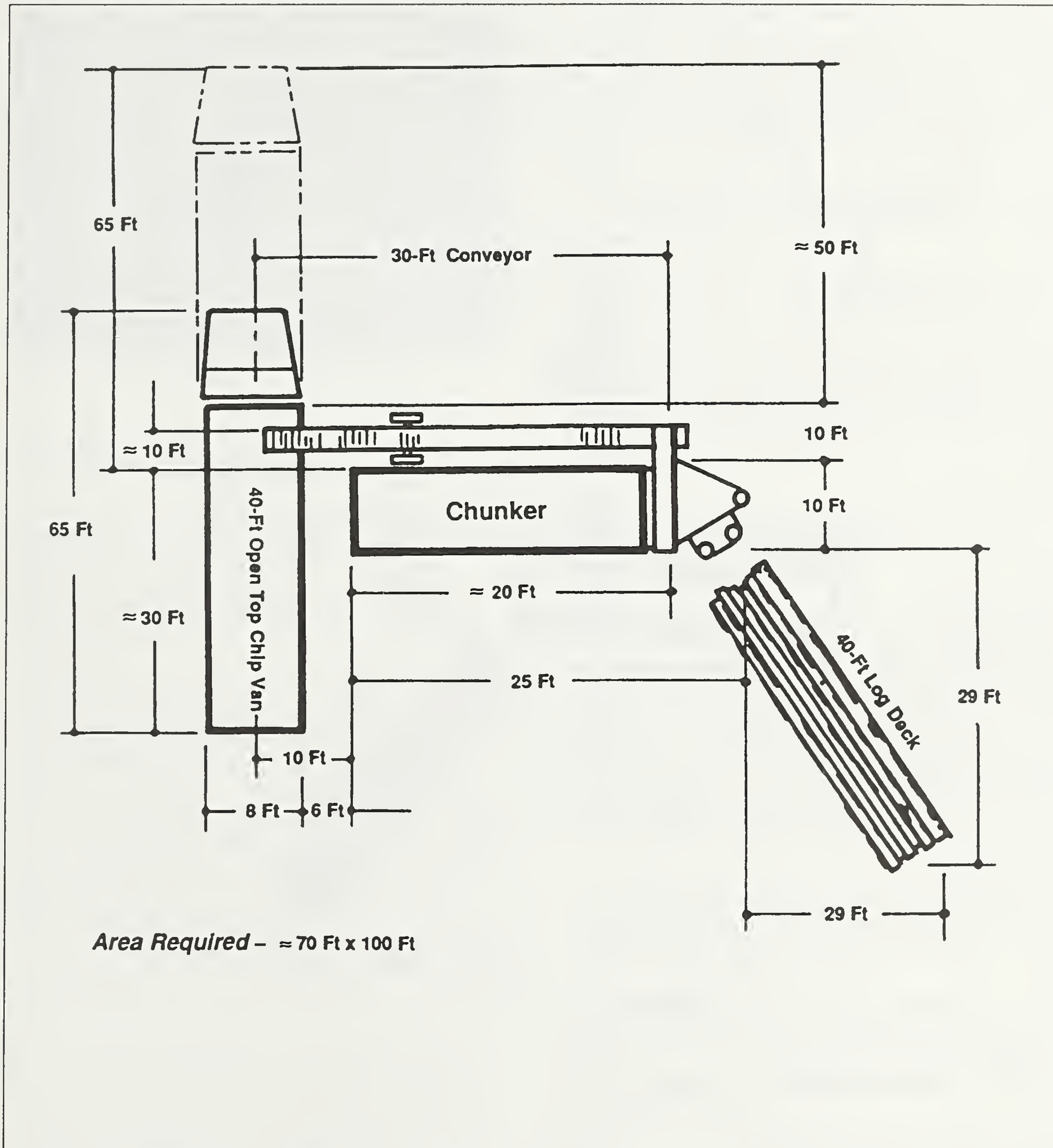

Figure 7.–Layout of van being loaded with van perpendicular (behind) to the chunker.

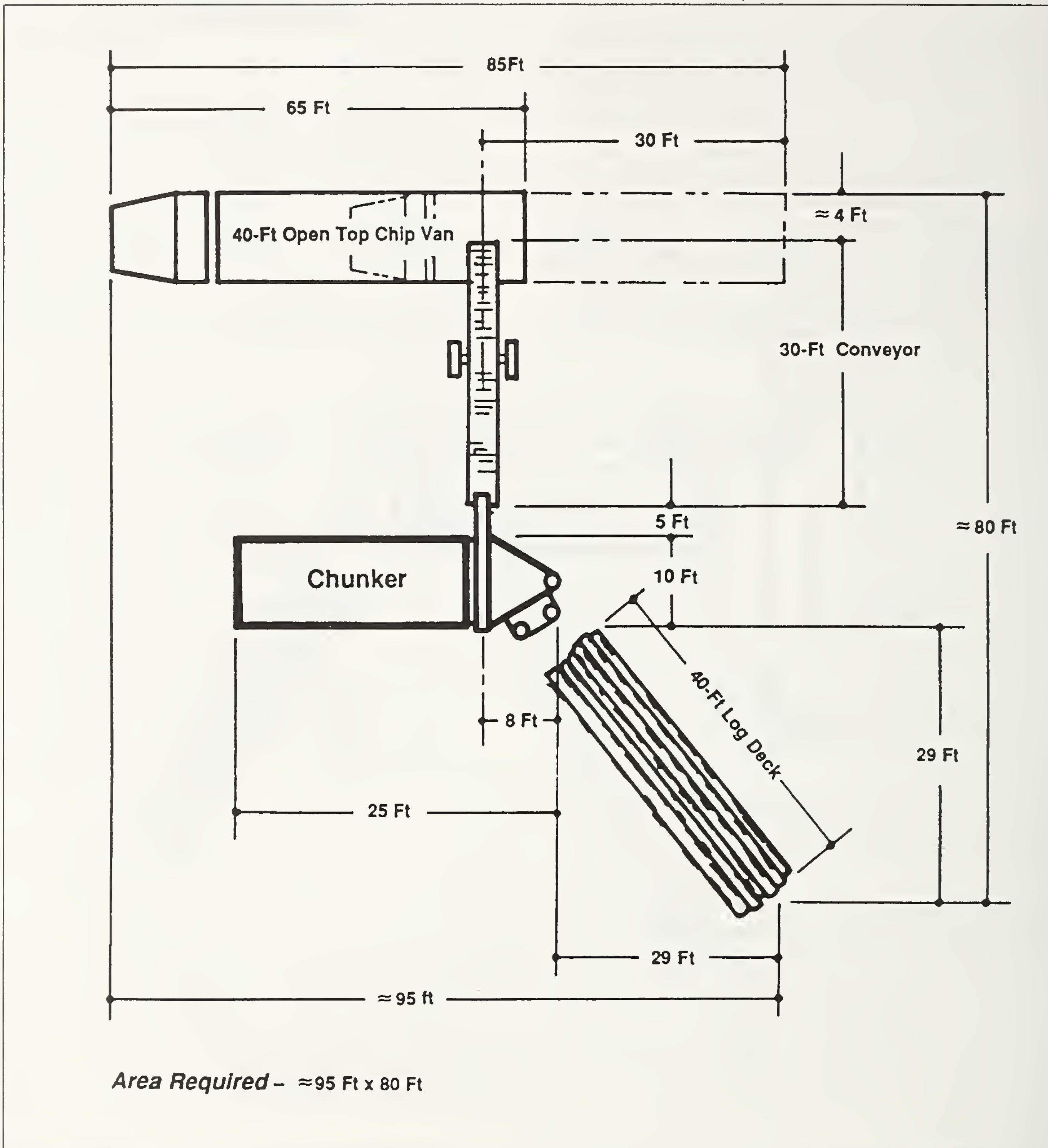

Figure 8.–Layout of van being loaded with van parallel to the chunker.

Figure 9.–Chunker incline conveyor in operating position.

Machine Operation

With all personnel clear of the machine, the belt clutch is tensioned, and the engine speed is slowly increased to 2,200 rpm. The cutter rpm is brought up to the desired speed (for most operations this is between 180 and 250 rpm). Increasing the cutter rpm with the same in feed rate produces smaller chunks; slowing the cutter rpm produces larger chunks.

Next, the feed system switch is turned on and the machine is ready. The feed rollers are opened. Material is placed on the lower roller and hydraulic pressure is applied to lower the top feed roller. The material will feed into the machine and chunking will take place. If the material fed into the machine is large and starts to bog down the cutter head (cutter wheel loses rpm), momentarily turn off the feed system switch until the cutter wheel regains rpm. Intermittently switch the feed system on and off until the obstacle is past. With large diameter butts, it sometimes works better to turn the feed system switch to *off*, open up the feed rollers, place the log butt on the lower feed roller, release the feed wheel control lever, and turn the feed switch to the *on* position to start the chunking operation.

When the chunking is finished, the conveyor and the feed system switches are turned off, and the cutter rpm control lever is returned to neutral. The operator can make sure that the cutter is not turning by looking through the view port in the cutter wheel housing. The engine rpm is reduced to idle and the machine is allowed to cool down at idle for 5 to 20 minutes before shutting off the engine.

In the event that the cutter blade becomes stuck in the material being chunked and stalls the hydraulic motor (maximum hydraulic system pressure is exceeded and oil goes over the relief valve), the feed system switch is turned off and the cutter wheel control lever is slowly brought to the neutral position. The lever is slowly pulled into reverse and the feed system switch is turned to the reverse position. The lever cannot be moved into reverse too quickly or the back edge of the blade will hammer into the uncut log and damage to the blade is possible. Once the material is cleared, bring the cutter wheel up to operating speed, turn the feed system switch to the forward position, and continue chunking.

Because of the limited visibility of the chunker operation, it is desirable to have a person by the machine watching the operation of the chunker. This person can also trim the excessively large limbs that will not be crushed by the feed rollers, insure that the chunks are not plugging the machine outlet opening or conveyors, and keep the area under the conveyors from building up with debris and stopping the lower conveyor.

MTDC Chunker Blade and Cutter Wheel

The cutter blades on the chunker must be checked daily to see if the edges have become dull or small stress cracks have developed near the clamping wedge and the blade interface. The blade cutting edges can be touched up with a disc grinder from underneath the blades or thorough the access door. The cutting edge of the blades should be maintained at a location one-third of the blade thickness from the outside surface (Figure 10). Usually the sharpening is done on the inside bevel. The bevel angle of the cutting edge should be a 60-degree included angle.

Most of the wear on the blade takes place about half way back from the front point of the blade. When wear on the blade becomes severe and proper clearance between the blade and anvil cannot be maintained or when cracks appear, the blades should be replaced.

Clearance between the cutting edge of the blades and the anvil should be kept at 1/16- to 1/8-inch (1.6 to 3.2 mm) (Figure 11). If the clearance becomes larger than 1/8-inch (3.2 mm), less shearing and more breaking takes place and more power is required.

The cutter blades are curved and trapezoidal in shape. The blade edge starts near the cutter wheel surface at the forward and tapers downward until it is at full depth at a point before the rear edge of the blade (Figure 12). The cutter blades are held in place by tapered locking wedges (Figure 13). The inside surface of both the groove and the locking

wedge has a 5-degree beveled surface so when the locking wedge is tightened, it will provide the radial locking force to hold the blade in place. When new blades are installed in the cutter disk, they are custom fitted into the grooves. Fitting the blades to an individual groove insures that good bearing contact between the rear blade edge and the cutter wheel is made to withstand the severe impact loads that occurs during chunking. After a blade is replaced, the torque should be re-checked on the capscrews holding the locking wedges in place after 2 hours of operation. Check the torque on these wedge capscrews daily. Large slivers or long strips of uncut wood will appear in the chunks. Some species like cedar are more susceptible to slivering than others. Occasional slivering will take place with all species.

The prototype cutter wheel developed at the North Central Experiment Station's Houghton Laboratory consisted of three blades mounted on the cutter wheel. The blades had a 2-1/2-inch (6.4 cm) pitch, which is the distance the edge of the cutter blade is toward the wheel center compared to the forward or leading edge. As the knife edge cuts into the tree or log, the cutter blade gets closer to the wheel center and causes the tree to feed into the machine.

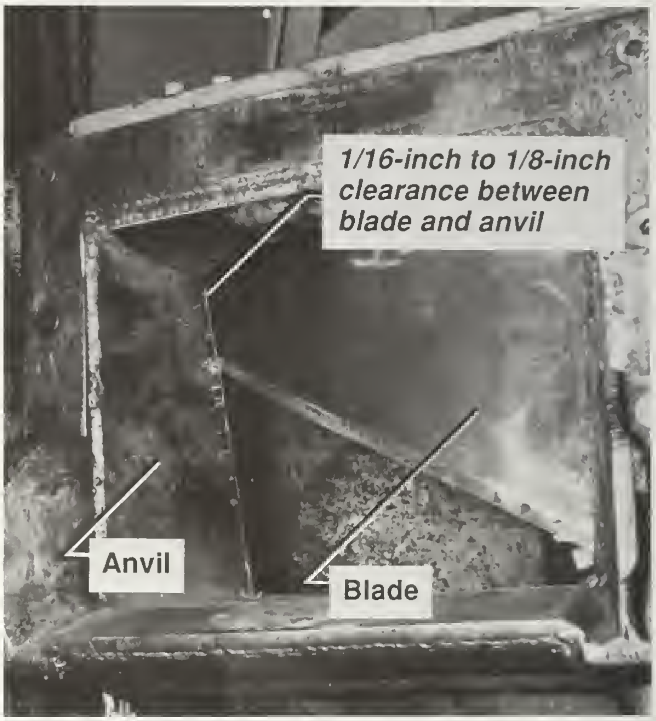

Figure 11.–Cutting edge surface and anvil clearance.

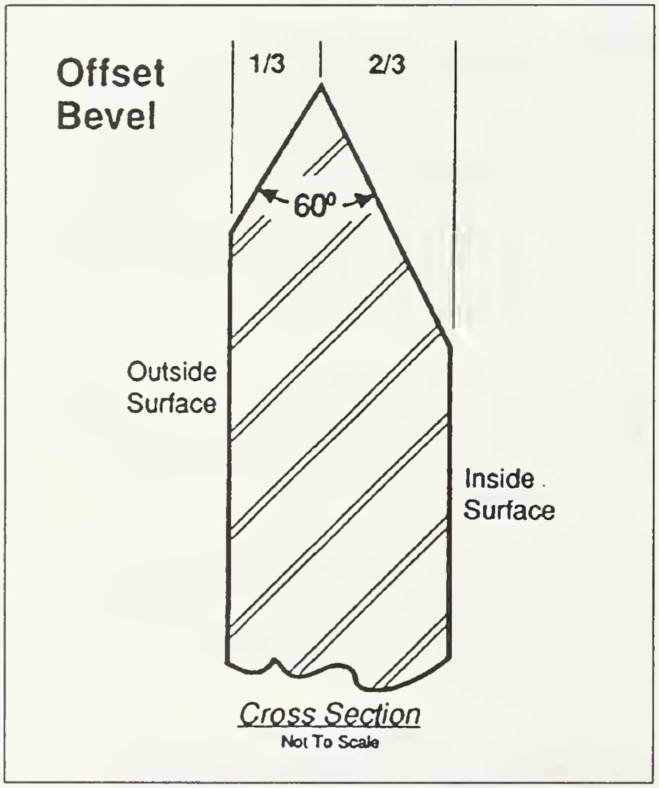

Figure 10.–Position cutting edge one-third of the blade thickness from the outside surface.

Figure 12.–Cutter blade.

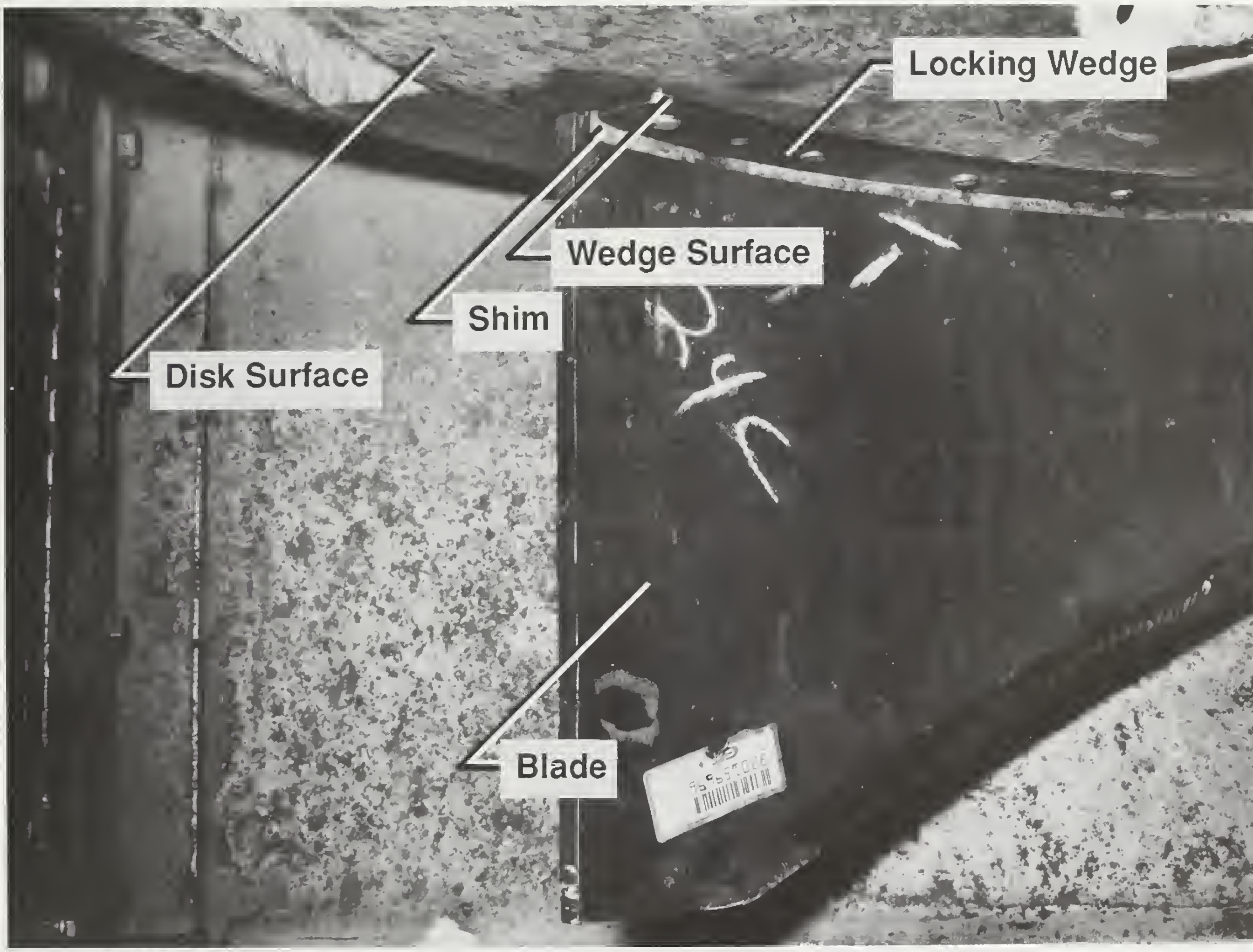

Figure 13.–Tapered locking wedge used to lock cutting blade to disk.

A prototype wheel was fabricated to evaluate the effect pitch had on chunk length. MTDC built a three bladed cutter wheel with no (0 inches/centimeters) pitch (Figure 14) and a cutter wheel that had four slots with two pitches. The cutter wheel was constructed so only two blades were used at one time and the two opposite blades had pitches of 2-1/2 inches (6.4 cm) and 4 inches (10.2 cm) (Figure 15). This wheel allowed both pitches to be tried without changing the cutter wheel. With only two blades, more time was available between cuts to allow the tree or material to move into the machine before the next cut was made.

The results of trying different cutter wheels with different pitches indicated that the pitch of the blade had a major effect on chunk length. The wheel consisting of three blades with no pitch would not allow the material to feed into the machine unless the cutter wheel was slowed to approximately 100 rpm. Then, potato chip like chunks were produced. The 2-1/2-inch (6.4 cm) pitch produced 2- to 5-inch (5 to 12.7 cm) long chunks, with the larger chunks being produced at slower cutter wheel speeds and higher feed wheel speeds. There was a limit to how slow the cutter wheel could be operated before the blade would stall and get stuck in the feed stock (tree). Enough flywheel energy had to be maintained by the cutter wheel to continue cutting. The 4-inch (10.2 cm) pitch produced the largest chunks, but the force on the blade pulling the material into the machine caused the blades to bend so this pitch was not used with the 3/8-inch (9.5 mm) thick cutting blades. Perhaps thicker blades would have withstood the increase in force without bending and 1/2-inch (12.7 mm) thick blades were fabricated but never tested. Figure 16 shows the chunk sizes produced with various pitch configurations. A different anvil was required with each of the different pitched cutter wheels.

Figure 14.–Cutter blade with three blades and no pitch offset. (Pitch is the radial distance between the leading and trailing edges of the blade.

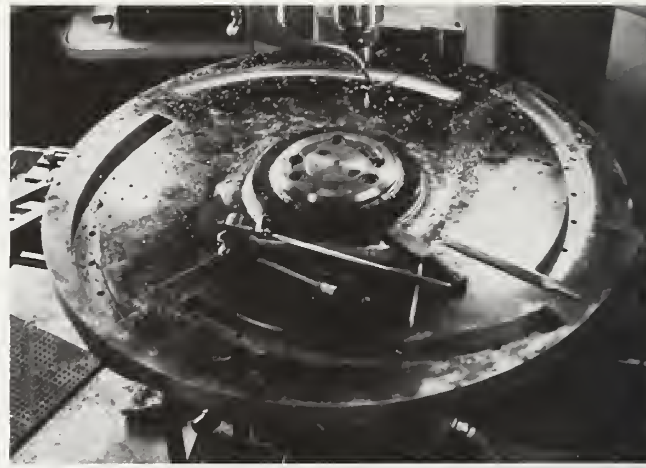

Figure 15.–Cutter wheel showing two different cutting pitches. Only two opposite grooves are used at one time.

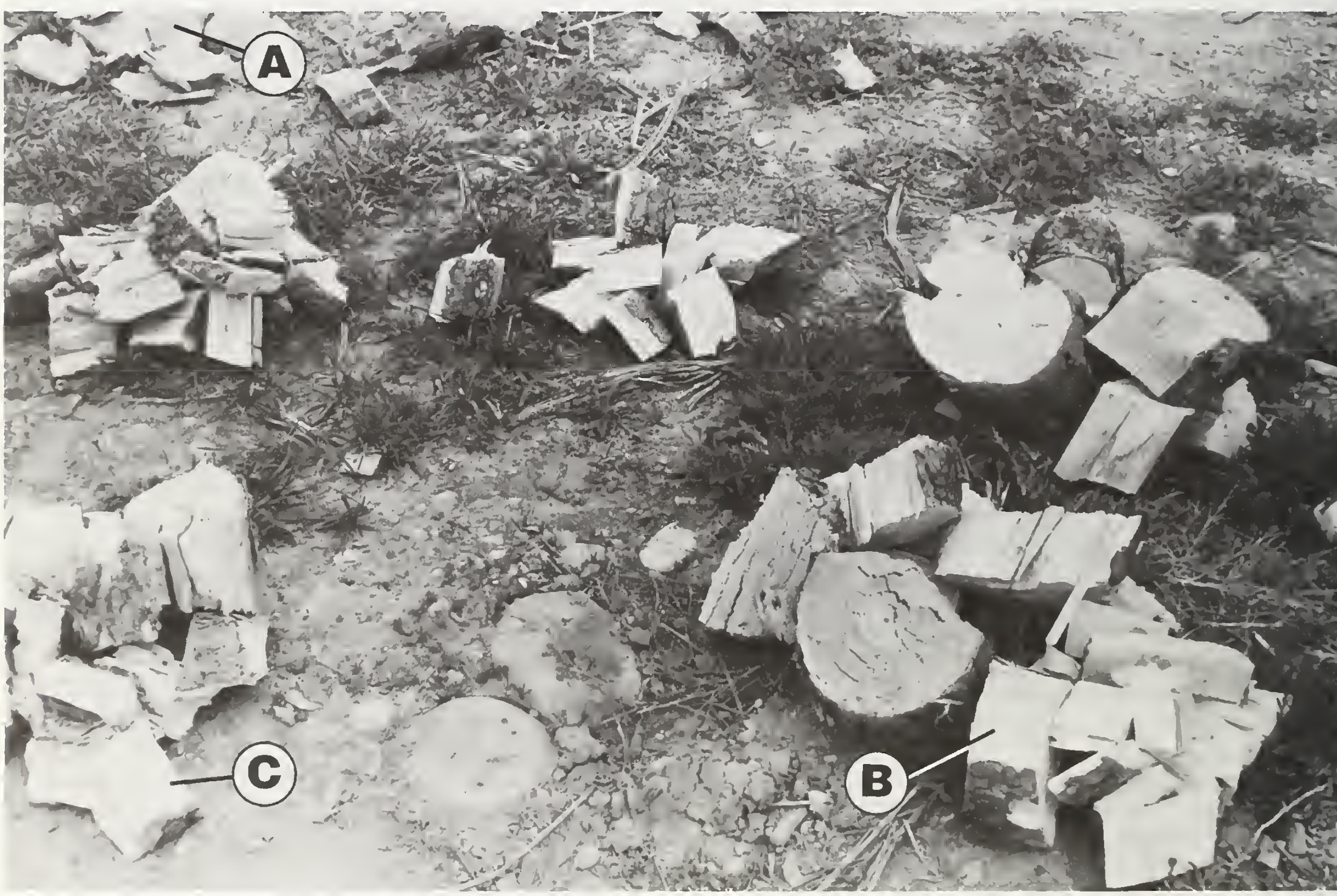

Figure 16.–Chunk size versus blade pitch. The upper left-hand corner shows chunks from (a) 0 inch or straight pitch cutter, (b) 2-1/2 inch pitch cutter, (c) 3-1/2-inch pitch cutter.

Tree species affected chunk shape. Green fir, spruce, and aspen produced disk like chunks. Some of the harder softwoods and most of the hardwoods produced smaller rectangular chunks. Dry, dead material produced smaller sliver like chunks (Figure 17). Usually the fiber length did not change with various species but the way the material fractured or stayed together was affected.

Figure 17.–Chunks in foreground are from green material and are larger and more intact. Chunks in background are from dry material. The fibers are approximately the same length but are smaller in size and more fragmented.

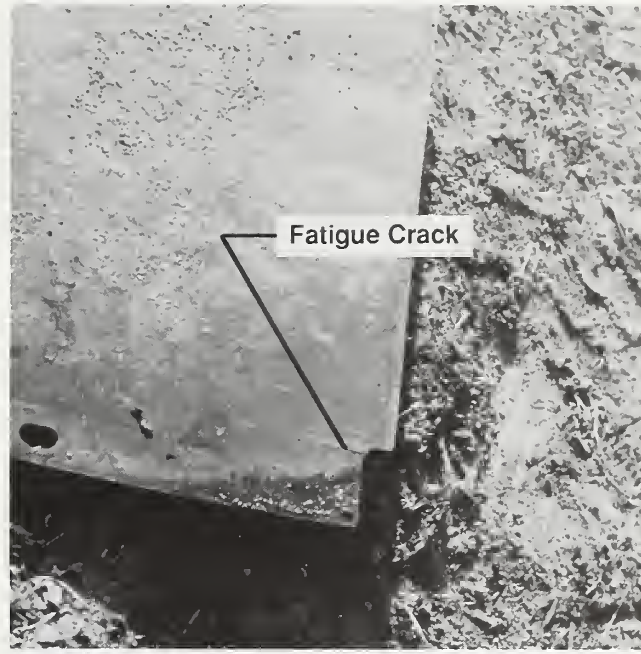

Figure 18.–Blade crack that developed at the edge of the blade/cutter wheel interface. The crack was possibly due to continuous flexing and metal grain structure alignment.

One of the problems incurred with the cutter blades was that cracks appeared at the blade-cutting wheel interface (Figure 18) when frozen hardwoods were run through the machine. The first modification tried was to add a rear support to the blade (Figure 19). This brace caused the blades to bend when a large frozen hardwood was being cut (Figure 20a). The brace was removed and the bending problem was almost eliminated. As the weather warmed, blade damage occurred less frequently. The first blades were made of T-1 steel to eliminate the need for heat treatment of the steel. Later blades were made of 4140 alloy steel heat-treated to 42-45 Rockwell C and the blade cracking problem was improved but not eliminated.

Figure 19.–Rear support added to blade to reduce blade damage and fatigue cracks. The device did not help remedy the problem.

It was essential that the blades were cut from the steel plate so that the grain of the steel was properly oriented, similar to required alignment when cutting a piece out of wood.

The location of the cutting edge on the blade was critical. Initially the cutting edge was located in the center of the blade. Slivering or banana peels occurred (Figure 20b) as

Figure 20a.–Blade damage sustained while cutting frozen hardwood.

Figure 20b.–Banana peels or slivers occurred as a result of flexing on the bottom of the blade.

the bottom fibers of the cut tree tended to bend down between the blade edge and the anvil rather than being sheared off. When the edge of the cutting blades was moved to the outside edge, bending occurred more often. Metal contact between the blade and anvil was quite frequent and blade edge wear was very pronounced. By positioning this cutting edge one-third of the blade thickness from the outside surface, better results were obtained.

The blade locking wedges appeared to loosen up almost immediately after installation. Once a proper sequence was established this problem went away.

During some of the field tests on chunking dry material, smoke appeared to come from the cutter assembly. An infrared temperature recording device used to record blade temperature after operating the cutter in dry material registered 450 degrees F (232 degrees C). The temperature of the blade cooled rapidly when the chunking stopped. If the machine is to be used in this material, a water spray device should be added to provide the cutter blades with some cooling and lubrication.

Anvil

Occasionally the anvil must be built up with weld or hard surface material. This is the result of abrasive soil that attaches to the logs during skidding to the machine and then is run through the chunker. After a new set of new blades are installed and properly torqued, the anvil surfaces should be built up to a clearance of 1/16- to 1/8-inch (1.6 to 3.2 mm) with the cutting edge cf the blade (Figure 11). Rotate the cutter wheel by hand before starting up the machine to insure that there is no interference between the blades and the anvil.

Because of the shape of the cutter blade, the anvil is difficult to fabricate (Figure 21). The anvil was fabricated after the

Figure 21.—Chunker cutter anvil.

cutter blades were installed. Any adjustments had to be made by filling the edges of the anvil with weld and then grinding the weld down to fit. Because of this, when new cutter blades are installed they should be indexed to the same location each time. This index point should be the front edge of blade. Each cutter wheel that has a different pitch requires a different anvil.

Initially banana peeling or slivering occurred during the cutting. A rear support bracket was added to retain the blade at the bottom edge to reduce the flexing which occurs and also provide a flat surface for the blades to cut against. This maintained the clearance between the blade and the anvil but caused problems with metal to metal contact and buildup of material around the anvil rear support bracket. This rear support bracket was eventually removed. A rounded corner was added where the cutting took place to solve the problem (Figure 22). This helped, but did not eliminate banana peeling. Moving the blade cutting edge to a position of one-third of the blade thickness from the outside surface resulted in almost entirely eliminating the problem. Commercial chunkers should simplify this anvil and provide adjustment for blade wear.

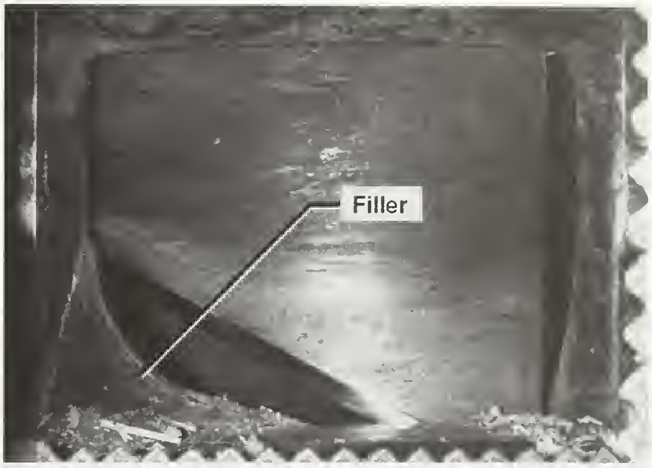

Figure 22.–Rounded filler piece added to corner of anvil to reduce slivering.

Procedures

Demonstrations

Both the Houghton Laboratory and the MTDC prototype chunkwood machines were used in the chunkwood roads research and demonstration effort which took place on the Chequamegon National Forest in Wisconsin (Figure 23 and 24) in 1987. A total of approximately 2.5 miles (4 km) of road were built at four different sites. The sites were chosen so chunkwood roads could be evaluated under a variety of roadbuilding situations:

- *A swamp crossing over deep underlying peat.*
- *A fine-grained soil with a high water table.*
- *A uniformly graded sand (sugar sand).*
- *An existing road with large mud holes.*

Some road segments were built with chunkwood only. Others were built with chunkwood in various combinations with sand, gravel, and synthetic (geotextile) fabric. Following construction the roads were subjected to truck traffic, and road performance was evaluated. The loaded trucks applied individual axle loads approaching 20,000 pounds (9,090 kg).

Roadway performance was evaluated based on: Rutting, lateral displacement, stiffness, and settlement.

The overall result of operational field tests was that all chunkwood roads performed satisfactorily. The general conclusion was that chunkwood is a viable alternative low-volume roadbuilding material.

Figure 23.–Chunkwood being dumped on road on the Chequamegon National Forest in Park Falls, Wisconsin.

Figure 24.–Chunkwood road in Wisconsin.

Laboratory Studies

Laboratory research was conducted to determine chunkwood compactability, compressibility, and water permeability. These laboratory studies were conducted in conjunction with the Chequamegon National Forest test roads. Results showed that as moisture content increased, compaction and compression increased and stiffness decreased The coefficient of permeability was found to be in the range of 20 to 115 feet per minute (6.1 to 3.5 m). These measurements are considerably greater than those for sand and gravel (Shook 1988). The investigators concluded that rational design procedures can be developed for chunkwood just as they have been for soil and rock (Hodek and Shook 1988). Chunkwood properties are summarized on page 2.

Information gained form this initial effort strongly supports expectations of a number of roadbuilding benefits that can be derived from chunkwood roads.

Following the initial chunkwood roadbuilding research and demonstration effort on the Chequamegon National Forest, the San Dimas Technology and Development Center in San

Dimas, California, aided in coordinating three Servicewide road projects to further demonstrate the use of chunkwood for lightweight road fills and temporary road surfacing. These roads were built at three locations:

1. The Bienville National Forest in Mississippi used chunkwood on top of non-woven geotextile fabric to construct a 650-foot (198 m) long section of road over an area of high-water content fine silt. In exceptionally wet areas on the Bienville National Forest, chunkwood depths apparently were insufficient at the interface of the chunkwood section and the conventional road and severe rutting developed at those locations (Vaught 1989).

2. The Kisatchie National Forest in Louisiana applied chunkwood to three fair weather roads. About 1 MMBF of timber was hauled over the first two test roads. The weather was not a factor during the haul periods and not much was determined from the test. Chunkwood was determined to perform satisfactorily under these conditions.

3. The Winema National Forest in Oregon used chunks on selected roads as a dust palliative treatment. Chunkwood was also used to elevate two roadways, then capped with about 6 inches (15.2 cm) of pumice. Upon drying during the summer months, the pumice layer had no binder and was dissipated by traffic, exposing the underlying chunkwood. The resulting chunkwood surface was difficult to negotiate (Buehler 1988).

In 1989, a contract logger constructed two roads in Northern Minnesota with chunks produced from pulpwood with the Houghton Laboratory's chunker. He reported satisfactory performance with chunkwood depths of 1 to 2 feet (30.5 to 61 cm), with or without clearing and grubbing before chunkwood placement (Bergstrom 1989).


Figure 25.–Chunkwood added to stabilize a clay pocket.


Figure 26.–Chunkwood fill.

Canadian Field Tests

The MTDC machine was sent to C & H Forest Service, Ltd., Clearbrook, B.C., to a site near Quesnel, B.C.., Canada. The wet summer of 1990 restricted some of the logging operations and some problems developed in clay pockets located on secondary haul roads Typically the clay pockets were filled with gravel and after a few truck passes more gravel fill was added or crawlers were used to pull the loaded trucks through. The problem spots were filled with chunkwood (Figures 25 and 26). The ability to handle traffic was improved and the clay pockets were stabilized. Trucks no longer had to be towed through the problem areas.

The machine was then sent to Ft. Nelson, B.C. where it was used for a demonstration road. In that area, secondary roads are built by removing the mineral soil and trucks then operate over the heavy clay subsoil. When the rainy season occurs, the roads become unusable and, even when the surface dries out, trucks have to be towed through some *gumbo* sections. About 1-1/4 mile (2 km) of a 2-1/2 mile (4 km) access road, were covered with 6 to 18 inches (15.2 to 45.7 cm) of aspen chunkwood (Figure 27). Production rates at the Ft. Nelson site were about 110 cubic yards an hour (83.6 m^3/hr) when the machine was set up at a landing and material was brought to it with a skidder.

It appeared that the chunkwood stabilized the heavy gumbo clay pockets in the road surface but was not necessary for much of the 1-1/4 mile (2 km) of the 2-1/2 mile (4 km) that was surfaced with chunkwood. However, in late September the weather changed and the area received some rain mixed

Figure 27.–Chunkwood road surface at Ft. Nelson, B.C., Canada.

with snow. Over the chunkwood portion of the road, hauling continued, but where the chunkwood ended, all operations ceased even for 4-wheel drive vehicles. The sections that were covered with 4 to 6 inches (10 to 15.2 cm) of chunkwood still carried traffic even though the chunks sank down into the road bed about 6 inches (15 cm) below the road surface (Figure 28).

The Canadian users agreed that chunkwood had great potential for their areas. They also considered it a possibility for seismic access corridors for oil and gas exploration.

Personnel at both B.C. locations felt that the machine should be improved by adding a self-propelled unit mounted on tracks with a knuckle boom loader that would reach out 30 feet (9.1 m) from the machine.

Figure 28.–Chunkwood particles permeated 6 inches into the clay road surface.

Forest Service Field Tests

In the summer of 1991, the MTDC chunkwood machine was then sent up to Coopers Landing, Alaska, to build a demonstration road on the Chugach National Forest. The road was built using different profiles with varying depths of chunkwood (Figures 29 and 30). The road was built during the fall and some early winter snow storms. Mobility became a problem when vehicles tried to climb a grade on the newly placed chuckwood/snow material. The chunkwood particles were suspended or lubricated by the snow and did not interlock. The snow also allowed more lateral displacement as traffic moved over the chunckwood/snow mix. Chunkwood had to be graded back into proper position in the spring.

These tests suggest that considerable work is still needed to determine where chunkwood is an appropriate roadbuilding material and to establish guidelines for designing chunkwood roads for various ground conditions.

Figure 30.–Chunkwood road with native fill top grade.

The optimum design for a chunkwood road depends on such factors as the specific ground conditions, strength, intended road life, volume, and severity of traffic. Results were compiled but not published (Appendix A).

Figure 29.–Chunkwood road on the Chugach National Forest in Coopers Landing, Alaska.

Other Chunkwood Applications

In addition to testing chunkwood as a roadbuilding material, it was evaluated for its ability to burn more efficiently than woodchips. Chunkwood has a higher bulk density than chips and therefore more weight in the same volume. This would reduce the cost of hauling. Chunkwood also stores better, reduces the chances of spontaneous combustion, and provides better drying when stored in piles.

The MTDC chunker was used on the Colville National Forest as a tool to be used for hazard reduction and biomass conversion (Figure 31). Tests were run on the Colville National Forest and Washington Water Powers' wood-fired generating plant at Kettle Falls, Washington, on the efficiency of burning chunkwood in lieu of burning hog fuel. Chunkwood was a more efficient fuel. It reduced the fuel costs 5 to 10 percent in one test, which was primarily the result of better drying of fuel in the storage piles. However, hog fuel was free and delivered to the power plant. Chunkwood had to be produced and hauled to the plant. The results were inconclusive on whether chunkwood burns efficiently enough to reduce stack emissions.

The University of Idaho also conducted a study on the production costs of producing chunkwood and the costs of hauling the chunkwood material (Johnson, Lee, and Hughes, 1989). Chunking costs were similar to costs of whole tree chipping. When chunking residual material, the cost per dry ton is $15 to $20/ton ($16.5 to $22/ton). When chunking green whole trees, as encountered in a thinning operation, the cost is $6/ton ($6.60/ton). There is slightly more cost with chunking and loading into trucks because a conveyor or truck occasionally has to be re-positioned. Conventional chippers blow chips into the trucks and it is easy to reposition the blow spout. Hauling light weight material processing "in the wood" is costly. It is easier and cheaper to haul the material in log form to processing mills. The bulk density of chunkwood is slightly higher than wood chips, therefore a truck with a given volume can haul more weight of chunkwood when compared to chips.

The chunker was sent to the Francis Marion National Forest in October 1989 to be used for slash reduction around the Witherby Ranger Station to reduce the fire hazard after the damage form Hurricane Hugo (Figure 32). The chunks were spread to enlarge turnarounds on a few roads but were not used for any road extensions. The turn-around with chunks provided soil stability during wet weather, but no evaluation other than visual observation of the road material took place.

Figure 31.–Colville National Forest, Kettle Falls, Washington hazard reduction and energy wood project.

Figure 32.–Hurricane Hugo hazard reduction around Forest Service facilities.

Discussion

Mike Gonsior (1989) summarized results of the Chunkwood Project field tests in a report for MTDC. The relatively low unit weight and high permeability of chunkwood are considered to be desirable characteristics for embankment and subgrade construction. Anticipated low durability (if untreated) may be considered undesirable for *permanent* roads, but otherwise unimportant or even desirable for *temporary* roads. The least desirable chunkwood characteristics are its relatively high frangibility and compressibility, and its relatively low stiffness and dimensional stability. But, these characteristics may be unimportant for many unpaved temporary roads or if the chunkwood can be buried at sufficient depth beneath the road surface.

Because of downstream aquatic habitats or domestic water supplies, the contamination of water that seeps through chunkwood may be unacceptable in certain circumstances, such as leaching of tannic acid from cedar and other species. However, concentrations of contaminants should be considerably lower if leachated from chunkwood than from wood chips or sawdust, due to higher permeability and a smaller wood surface area exposed to contact with the ground water.

Perhaps cost is the greatest obstacle to further applications. Some of the experimental applications described in this evaluation were deemed too expensive; but it is expected that a *mature* technology would be more efficient.

Also, often the right-of-way timber volumes would be insufficient to provide all of the raw material needed for a road bed and would have to be supplemented from sources outside the right-of-way. Accordingly, discussion of the status of technology might need to be broadened to include logging technology. If chunking is to occur away from road construction sites, then technology for loading and hauling chunkwood also should be discussed.

In gentle terrain, the greater potential for chunkwood appears to be in wet areas or where the subgrade soils are otherwise weak. But regardless of the strength of native subgrade, it is usually preferable to elevate the roadway on flat ground to promote subbase drainage and to minimize water accumulation on the roadway. This can be done either by turnpiking or by end-dumping borrow material. Using chunkwood to elevate the roadway might be preferable to other alternatives. However, because chunkwood is relatively compressible, it must be either buried at appreciable depth beneath the surface or consolidated after placement on the surface, if severe rutting is to be avoided. This compaction should be planned for by placing additional thickness of chunkwood.

Permafrost is a special gentle-terrain condition wherein chunkwood could be especially beneficial, whether buried or placed on the surface, because of its light weight and relatively good insulating qualities.

In steep terrain, the relatively light weight and high permeability of chunkwood makes it ideal for fill construction and for backfilling behind retaining structures, provided that groundwater contaminated by passage through it can be either treated or prevented from stream entry.

Elevating the roadway in steep terrain to eliminate or reduce the height of exposed cut bank might also be desirable in many circumstances. Chunkwood could be an acceptable substitute for borrow material that would ordinarily be needed to accomplish this. Placed upon a slope after only minor clearing and excavation, such a chunkwood prism should have virtually no effect on the hydrologic functioning of the slope; and the combination of its relatively light weight and the shallow excavation before its placement should reduce both cut and fill slope stability problems. Reduction or elimination of cut slopes should reduce soil erosion and attendant esthetic and stream sedimentation problems and should also enhance subsequent logging operations.

Native soil and rock may be considered preferable to chunkwood for top surfacing in most steep terrain circumstances; but, chunkwood could be utilized for building stable embankments or structures, surfaced to support anticipated traffic.

Whether in steep or gentle terrain, it can be advantageous to combine chunkwood in various proportions with sawdust and woodchips or with native soil and rock. There might also be other admixtures, such as Portland cement or asphalt, that would enhance chunkwood performance as well as extend its useful life. Geotextiles can also improve performance. Secondary experimentation along these lines might be incorporated in proposed research and development efforts.

At a rate of about 300 MBF, 600 cords, or 1,500 green tons per mile (843 tons/km) in flat terrain, the cost for chunkwood could be in the vicinity of $15,000 per mile ($9,300/km) (assuming logging and chunking costs of about $50 per MBF ($9.31/m^3), $25 per cord, or $10 per green ton ($11.00/ green ton). In steep terrain, the quantities of chunkwood required per unit length of road might be at least five times those required in flat terrain, assuming the entire road prism is constructed of chunkwood. Correspondingly, chunkwood costs might be more than five times the flat terrain costs—perhaps over $100,000 per mile ($62,000/km), because logging on steep terrain is usually more difficult and more expensive than on flat terrain. Therefore, especially on steep terrain, it seems likely that chunkwood will be used only occasionally to deal with particular problem situations,

rather than continuously throughout the entire length of a road. Accordingly, the problems of transition between sections of chunkwood road and sections of conventional construction will need to be addressed.

Durability of chunkwood is a matter of concern. Some expect it to deteriorate relatively rapidly, but consider this to be advantageous for so-called temporary roads. Others, however, have found sawdust and wood chips to remain substantially unchanged after several years of service, and therefore conclude that concerns about chunkwood durability are unwarranted. This issue probably will be resolved only by experience in various climates, and cannot be dealt with adequately in our short-term research and development efforts. The roads built on the Chequamegon National Forest have been in place for 6 years and are still very usable. Submerged material, in situations such as swamp crossings that remain wet, has been in place in Minnesota for 15 years and is in excellent condition.

Eventually, development of new equipment as well as appropriate techniques might be needed to render chunkwood roads economically viable. For example, chunker technology might need to be altered or combined with splitting or crushing technology to handle large trees. It might also be advantageous in some situations to have a self-propelled, all-terrain chunker, integrated with timber felling and retrieval technology that was capable of building roads in a one-pass operation. Alternatively, there might be need for improved chunkwood hauling technology for situations where on-site chunking is not a viable option.

In the near term, however, it is likely that equipment development efforts will be limited to maintenance, minor improvements, or duplication of existing chunker technology. Consequently, costs incurred for near-term test and demonstration projects will probably continue to be high when compared to costs that might be anticipated with new, specially designed equipment.

The chunkwood roads built and tested so far have done little more than expose the potential of chunkwood as an alternative roadbuilding material. There are many basic engineering, economic, and logistic questions that must be answered before we fully understand how to properly design and build chunkwood roads under a broad range of roadbuilding situations. Forest road design engineers have the benefit of knowledge gained through many years of designing and building conventional gravel, sand, or shot rock roads. We now need to develop the same kind of understanding and experience for chunkwood roads.

Chunkwood and chunkwood roadbuilding are emerging technologies. Commercial wood chunking machines and complementary chunkwood roadbuilding equipment are not available. Forest Service demonstrations of wood chunking machinery and chunkwood roads have resulted in some interest in this technology by the equipment manufacturing industry. However, widespread interest in chunkwood roads has not developed in the Forest Service. Robust wood chunking machinery must be developed by industry before the expected benefits of this technology can be fully realized.

A major objective of this project was to encourage the commercial development of wood chunking machinery and specialized chunkwood roadbuilding equipment, because an established market would stimulate practical implementation of chunkwood roadbuilding technology. That has not occurred.

Another objective of the project was to provide information to the field on where chunkwood technology can be applied to reduce road building costs for low volume roads and to provide an alternate material for building roads in problem areas (swamps, bogs, etc.). To provide Forest Service personnel with information that would help them design roads for chunkwood materials, the Alternate Surfaces Program should be revised and design information should be published.

Conclusions

The chunkwood road field tests demonstrated that chunkwood is a viable alternative low-volume roadbuilding material.

Chunkwood is an excellent lightweight fill for use on swamps and muskeg. It stabilizes soils such as clay and sugar sand, and eliminates mud holes, ameliorates road dusting, and can, by itself, support traffic. It can also be effectively combined with sand, gravel, and geotextile fabric to improve performance.

Commercially manufactured hardware would improve machine availability and reliability and would reduce the costs associated with building chunkwood roads. When commercial chunkwood machines are available, the potential exists for long-term benefits to the Forest Service in road cost savings and conservation.

Chunkwood and chunkwood roadbuilding are emerging technologies. Commercial wood chunking machines and complementary chunkwood roadbuilding equipment are not yet available. Chunkwood roads demonstrated and tested to date have been made possible with prototype wood chunking machinery. Although it was possible to construct and test chunkwood roads with prototype wood chunkers, their reliability adversely impacts the development of reliable cost information on chunkwood roadbuilding. Many improvements have been made on the present chunkers but further improvements are necessary.

Some work needs to be done with the potential manufacturer to provide technical Information so an acceptable machine will be developed for production of the chunkwood product for future roadbuilding projects. Forest Service demonstrations of wood chunking machinery and chunkwood roads have resulted in some interest in this technology by the equipment manufacturing industry. Robust wood chunking machinery must be developed by industry before the expected benefits of widespread usage of this technology can be fully realized.

Recommendations

The present chunker should be maintained for demonstrations and chunkwood road projects. Because the present machine is a prototype and not a production machine, the actual costs are higher than one would expect if a commercial machine were available. This would change if a manufacturer would start building a wood chunker.

Additional studies and development in certain aspects of the program will be needed, such as using other forms of wood (perhaps hogged residues) for road construction, using chunkwood for erosion control, using chunkwood in gabions or for backfill behind retaining walls. Studies should also be conducted to determine if water is contaminated by seeping through chunkwood and to identify alternatives for loading, hauling, and placing chunkwood.

Recommendations of items that need improvement on the existing prototype chunker are:

The machine should be able to handle larger diameter material. The present 3/8-inch (9.5 mm) thick by 14-inch (35.5 cm) deep blades are marginal and increasing the depth of cut would require thicker blades or a different cutter head design. A cutter with disks on both sides of the blade would probably solve the problem.

The blades should be easier to replace and the anvil should be adjustable to accommodate wear.

The feed into the machine should be such that the debris caused by slippage of the feed rollers on the trees and the broken off branches would pass on through the machine onto the conveyor instead of accumulating around the feed roller.

The machine would be more flexible and have broader application if it were track mounted, if it had a knuckle boom loader instead of a slide boom loader, and if it contained the loading conveyor on the machine itself rather than requiring a portable extra loading conveyor to be provided.

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Appendix A–Chunkwood Summary of Test Roads

APPENDIX A

ROUGH DRAFT

CHUNKWOOD
SUMMARY OF TEST ROADS

PROJECT NO. 8E82L16

APRIL 1991

R.KARSKY

SITE: Hayward, WI - Chequamegon NF FR 481

DATE: Feb. 1987

SITE DESCRIPTION:

This section of road was a swamp crossing and the adjacent roadway. The total length of road was 0.67 miles. The project included an existing grade with a 1700 ft. relocation of which 600 ft. was though a swamp. Soils were classified as loamy sand with the swamp being classed as Carbondale. Aspen, black spruce, and brush were the predominant trees. There was a substantial depth of peat beneath the vegetative swamp mat. The maximum peat depth was 18 ft. and it had a high moisture content and very low shear strength.

DESIGN DESCRIPTION:

This road includes three test sections involving chunkwood:

1. The first 250 ft. across the swamp, where the swamp was the shallowest, had 30 inches of chunkwood placed directly on the vegetative mat.
2. The next 350 feet across the deepest part of the swamp called for the placement of an 8-ounce geotextile fabric on top of the ungrubbed swamp followed by 24 inches of chunkwood. A 4-ounce geotextile fabric was placed over the chunks, and a minimum depth of pit-run gravel was placed on top of the fabric as the surfacing course. The geotextile fabric was used only for the purpose of providing a separator to keep the chunks from being pushed into vegatative mat and to keep the gravel from mixing with chunkwood. The chunkwood was essentially enveloped by fabric.
3. The third section was built on loamy sand and chunks were mixed with soil. The goal was to produce a 50/50 mix but with mixing done in place with a front end loader, much variation existed. Prior to testing, this section was vibratory roller compacted. This was the only section compacted.

SUMMARY:

After construction the chunkwood road test sections were tested by making multiple passes over the road with tandem axle dump trucks loaded to a GVW of 50,000 pounds. Rear axle loads were about 20,000 pounds per axle. Performance was evaluated by measuring rutting, lateral movement of chunkwood in road bed and roadway stiffness. After about 60 passes, severe rutting had occurred at the junction of the swamp crossing. The test was stopped and the road re-bladed. An additional 50 passes were made with no further re-occurrence of the previous problem.

Rutting did occur after the truck passes especially where there was no geotextile fabric. The surface channelization was easily corrected by motor grading and rutting did not develop when vehicles were allowed to off-track. The chunkwood did not show unacceptable compaction or material

loss due to traffic. Lateral stability of chunkwood fills were extremely good. The performance of a chunkwood/soil mix was inconclusive. This was due to a heavy rainfall just prior to testing and the inconsistent blending of the mix.

Summary: (contd) Hayward, WI site

The use of geotextile fabric acts as a reinforcement and can measurably increase the section's stiffness as the plate loading tests indicated. It was also an effective separator to prevent the loss of surfacing aggregate into the voids of the chunkwood lift and the loss of the chunkwood particles into the underlying mat.

RECOMMENDATIONS:

Swamp or muskeg crossings stand out as an excellent application for lightweight chunkwood fills. In such an application it is recommended that trees and slash from the right-of-way clearing that are not recovered for chunking be concentrated in the area of intended forest road. Unless the road is to have an extremely short life, it is also recommended that an 8-ounce geotextile fabric be placed over the concentrated slash before applying the chunkwood. The combination of fabric and slash will strengthen the swamp mat, and the fabric will prevent the loss of chunkwood particles to the underlying peat through the natural holes in the vegetative mat. Without the fabric separator, the chunks inevitably will be pumped through these holes under load of the traffic.

In a swamp crossing application, the load supporting capability of the road is critical and is directly related to the overall depth of the road. A chunkwood lift of at least 30 inches is recommended of the entire road is to be built of chunkwood. Chunkwood roads can be readily re-shaped and more chunkwood added as needed from a nearby stockpile. Where the chunkwood is to be enveloped in geotextile fabric and covered with a aggregate surfacing course, a mimimum chunkwood depth of at least 24 inches is initially recommended for the swamp crossing.

Observations 3 years later showed the the road was in good serviceable condition. Water flow was observed to be still passing under the roadbed due to slightly different water levels on each side of the roadways and slight currents evident on the low side.

SITE: Chequamegon NF - Medford Site - FR 583 - Medford, WI

DATE: March 1987

SITE DESCRIPTION:

This was a poorly drained site with soils classified as silty loam to sandy loam. The total length of the project 1.14 miles including a 3,000 ft. section having assorted chunkwood sections. The remainder was built of pit-run gravel. The timber stand was predominantly aspen and sugar maple with pockets of lowland brush and tamarack. The nature of the soil on this site makes it impossible to operate conventional logging equipment during the spring of the year and during wet periods.

DESIGN DESCRIPTION:

This test road was laid out to include six different design sections involving chunkwood. The sections included:

- -Chunkwood only
- -Chunkwood on geotextile fabric with and without surfacing aggregate
- -Chunkwood completely enveloped in fabric followed by a surfacing aggregate
- -Fabric used only to separate the surface aggregate from the underlying chunkwood
- -Surfacing aggregate placed directly on top of the chunkwood.

The road sections were not compacted prior to being tested. Immediately after the chunks were produced they were loaded into dump trucks and spread on the roadway. Only a 4 once geotextile fabric was used on the road sections containing fabric.

SUMMARY:

After construction the chunkwood road segments were tested by making 105 passes over them with FS tandem axle dump trucks loaded to a GVW of 50,000 lbs. This equated to a 20,000 lb axle load. The roadway performance was evaluated by measuring road rutting, lateral shoving, and roadway stiffness. Plate load tests indicated that road sections constructed of gravel/geotextile/chunks were stiffer than sections of chunkwood/gravel, chunkwood/geotextile, or chunkwood alone. Although the stiffness or the roadway sections varied, none of the tests that were conducted revealed classical load-bearing capacity failure. This was probably due to the test procedure used on the site. Insignificant lateral movement occurred due to the truck traffic.

The use of geotextile fabric acts as a reinforcement and can measurably increase the section's stiffness, as shown by the plate loading tests, when the fabric is appropriately located in the cross section. It was an effective separator to prevent the loss of surfacing aggregate into the voids in the chunkwood lift and the loss of some chunkwood particles into an underlying swamp mat. Rutting that occurred during testing could easily be corrected by "off-tracking", or minor blading.

It was found that the moisture content of chunkwood had a measurable effect on creep, stiffness, and compaction. As the moisture increased, creep increased, stiffness decreased, and compaction increased. It is felt that the effects are due in part to the fact that the wood strength varies inversely with its moisture content.

RECOMMENDATIONS:

These initial trials have introduced the concept of chunkwood roads and has demonstrated that chunkwood is a viable alternative roadbuilding material. Availability, bottom-line economics, or some other engineering justification will ultimately influence the choice of materials, whether it be chunkwood or conventional roadbuilding gravel.

With fine grained soils high in clay content and a water table near the surface, catastrophic road failure, as in a swamp crossing, is not the problem. The problem is to maintain a road that retains its trafficability and does not become a quagmire under extreme wet ground conditions. Chunkwood will not become a quagmire. The only recommendation here is that the bed of chunkwood be deep enough to keep the road surface sufficiently elevated. This would be true whether the road is made entirely of chunkwood, or if fabric and surfacing aggregate are used in combination with chunkwood.

Definitive data on life expectancy are not yet available, it is hypothesized that a road built only with chunkwood would have a shorter life than one where chunkwood is completely enveloped in geotextile fabric and then covered with a surfacing course of pit-run or crushed aggregate. Surface exposed chunkwood is likely to rot faster than chunkwood buried under saturated soil. This hypothesis is based on the soundness of old corduroy roads that have uncovered and have been buried for years. Observations of the road site 3 years later has shown that some decay had taken place where the chunkwood was wetted in spring and then dried out during the summer but that road was still very serviceable even with little or no maintainence.

SITE: Chequamegon NF - Washburn Site - FR 691B - Ashland, WI

DATE: March 1987

SITE DESCRIPTION:

This site involved 0.6 miles of new construction. The soil is classed as a medium to coarse sand often referred to as "sugar sand" because of the similarity to granulated sugar when dry. Due to the lack of cohesion and it's uniform particle size, these soils have very little capacity to support traffic when dry. The timber on this site was mostly jack pine with smaller amounts of aspen and scrub oak.

DESIGN DESCRIPTION:

The road built on sugar sand had 5 different design sections. Three sections received 4, 8, and 21 inches of chunkwood only. For the latter no grubbing was done. A fourth section received a surfacing course of at least 6 inches of sugar sand placed on top of a 15 inch chunkwood base again with no grubbing. In the fifth section the sugar sand was mixed with the chunkwood in a targeted 50/50 mix. The road was 21 inches deep with no grubbing. Mixing at this site was achieved by trickling sand on to the the conveyor carrying chunks to the dump truck. There was considerable variation in the mix consistency. No fabric was used on this road. Compaction with a vibratory roller compactor was done on portions of several test sections.

SUMMARY:

The test sections were subjected repeated truck traffic to evaluate roadway performance. Tandem axle dump trucks were loaded to obtain axle loads of 20,000 lbs. and 200 passes were made over the road surface. The chunkwood did not show an unacceptable compaction or material loss due to the traffic. Lateral stability of chunkwood fills was exceptionally good. Surface rutting caused by traffic channelization was easily and quickly corrected by motor grading and rutting did not develop when vehicles were allowed to "off-track" the previous traveled path.

As little as 4 inches of chunkwood placed directly on top of "sugar sand" effectively improved the stability of the road, and as an added benefit significantly reduced the dusting problem. A deeper surfacing course of chunkwood all but eliminated the dusting.

When a top course of sand placed over chunkwood was too deep, rutting occurred and the sand surface tended to displace laterally until the chunkwood layer was reached.

About 1 MMBF of pulpwood was hauled out on the chunkwood road during the year following the road construction without problems.

Observations 3 years later found the road to be firm and in good serviceable condition. The moisture was retained by the chunkwood on the road surface to stabilize the sugar sand.

RECOMMENDATIONS:

"Sugar sand" can be stabilized by applying a relatively shallow, (4 to 8 inch) surfacing course of chunkwood. Besides stabilizing the sand, it reduces severe dusting from traffic.

Stabilizing uniform sand can also be achieved by using chunkwood as an admixture. A high proportion of chunkwood to sand is recommended. Although there is no supporting data, a 80/20 mix by volume is initially suggested. Ideally, the best performance should result when the chunkwood particles are in contact with each other with the void between the particles filled with sand.

SITE: Chequamegon NF - Glidden Site - FR 325 - Glidden, WI

DATE: March 1987

SITE DESCRIPTION:

This was an existing grade with a total length of 0.1 miles that included a 300 ft long section of mud holes with free standing water. The soils ranged from loamy sand, to sandy loam/loamy sand. The timber stand included black spruce, swamp hardwoods, spruce hardwoods, spruce-fir, and northern hardwoods.

DESIGN DESCRIPTION:

This road was initially impassible early in spring due to the standing water on the roadway surface. The road was constructed solely to determine whether chunkwood could be used to fill in large mud holes within existing roadways. Chunks were hauled to the site from a stockpile, dumped onto the roadway, and bulldozed until a roadbed surface was established above the level of the standing water. The chunks displaced the standing water, remained in place, and allowed the water to flow under the driving surface. Surfacing aggregate was then placed over the chunkwood base. Although this road received some traffic no research was done.

SUMMARY:

Chunkwood performed adequately as a material to stabilize mudholes and areas that frequently have standing water in the roadway. The permeability of the chunkwood allowed the slow moving water to pass under the roadway while still maintaining trafficability on the road surface.

RECOMMENDATIONS:

Chunkwood is an adequate material to be used to stabilize mud holes and can be used in areas that occasionally have free standing water on the road surface area. It will allow slow moving water to flow under the roadbed and yet maintain trafficability on the road surface.

SITE: Bienville NF - Strong RD - Jackson, Mississippi

DATE: June 1988

SITE DESCRIPTION:

A portion of a road, (650 ft of a 2300 ft long road), constructed by the purchaser under a timber sale contract was constructed of chunkwood. The road was located in a low wet location with a soil type of mainly silt. Finding a source of material for the chunkwood was a problem. "On site" timber was not used because it was involved in the timber contract. As a result of the time of the year and time constraints, pulpwood was purchased on the open market and hauled from an adjoining state to be processed into chunkwood.

DESIGN DESCRIPTION:

The road bed location was cut out with the stumps cut as close to the ground as possible instead of grubbing them. The old stumps and vegetative mat does provide some additional support over the silt soil. A non-woven fabric, Trivira S1135, was placed under the chunks. A chunkwood depth of 12 inches was recommended and an actual depth of 18 inches was used in the softer portions of the road. Because of the increased depth of chunkwood in these areas, not enough material was available to cover the original chunkwood section. The chunks were dumped over the mat and spread with a D-4 crawler. Clay gravel was placed over the Trivira S1135 and Mirifi fabric to a depth of 9 inches in the remaining section of the road that was originally designated to be constructed with chunkwood. This section of road performed well.

SUMMARY:

During road construction the road bed tended to float and did not compact. The road was floating over the soft silt. Under the high wheel loads as the chunks were placed over the fabric, the chunks evidently punctured the fabric, forcing the mud up and moving the chunks down thru the silt under the fabric. After the chunks were placed, work stopped until weather conditions improved to complete the remaining sections of road.

About two months after the construction of the road, logging of the FS timber began and was completed 4 months later. 240 log truck loads and 40 loads of pulpwood, (a total of 970 MBF), were hauled out over the road. Rutting did occur to a maximum depth of 12 inches during hauling. The road had to be bladed twice a day, (after about every 6 truck loads), to keep the chunks on the road. The chunks had broken down to fist sized and smaller pieces but tended to squirm out from under the truck tires. The chunks held moisture and worked well as a dust abatement material. The rest of the road was ankle deep in dust.

RECOMMENDATIONS:

For chunkwood to be an viable and economical alternative road building material, the raw material for chunkwood should "on-site" or close to the construction area. If "on site" wood was used the cost of this road would be substantially less.

Recommendations: (Cont'd) - Bienville NF

On wet sites when fabric is used for an underlayment, the fabric should be of woven construction, not the non-woven fabric used here. Once the fabric was torn, chunkwood "pumped", or worked its way down into the silt and rutting occurred.

A stockpile of chunked material should be available for repair of unstabilized soil or roadbed. With the additional chunkwood material added to the roadbed to stabilize any of the problem areas, maintenance should be reduced. "Off tracking of the vehicles would also tend to heal up the road surface.

In wet areas where there is little soil strength, a depth of 24 to 30 inches of chunkwood sub-grade should be used.

SITE: Winema NF - Chemult RD - Chemult, OR FR 9409

DATE: March 1988

SITE DESCRIPTION:

The test site was located on FR 9409 on Walker Rim, located 75 miles north of Klamath, OR. The road was on a basalt rim overlaid with volcanic deposits of pumice and ash. The pumice soils have rapid infiltration and permeability rates. Annual precipitation is 15 to 40 inches and most moisture is in the form of snowfall. During the early spring season when the road bed is wet and the water table is high, the road "troughs" due to the poor drainage and weak soil strength. However, because of the rapid infiltration rate these soils dry out quickly and dusting occurs. Piles of precommercial thinnings were located near the chunkwood road site. These piles date back to 1985, with the diameter of the material available ranging from 3 to 12 inches, with an average diameter of 4 inches. These piles had dried out and settled. Initially the slide boom loader on the chunker was used to pull the material from the pile. When the material was out of reach of the chunker the machine was re-positioned and the operation repeated. This proved to be time consuming and not cost effective.

The original intent was to produce two grades of chunkwood, a course grade for road fill in areas of poor drainage and a finer grade for use as a finish course. Because the chunkwood couldn't be maintained at a size of 3" maximum, (the size required for a top coat dust palliative), the chunkwood was only used as a subgrade reinforcement and roadfill. Native material or pumice was added as a topgrade surface material.

DESIGN DESCRIPTION:

Initially chunkwood was hauled and placed to a 4 inch depth on the existing roadbed an left exposed for compaction by hauling equipment and evaluated as a running surface. The large chunkwood size and loose texture restrained truck speeds to less than 10 mph. The chunkwood was then road mixed with the pumice subgrade and compacted by repeated haul. This still left a rough running surface so an alternative construction technique was employed.

The existing travel way was excavated approximately 6 inches and the material was windrowed to the outside limits of the roadway. Chunkwood was hauled and placed to a 6 to 8 inch depth, compacted by hauling equipment and the windrowed material was folded back over the chunkwood lift and the road bladed to the design template. Native material was added to the surface to provide a cover of 6 inches over the chunkwood to increase riding comfort and provide a depth of cover sufficient for maintenance blading without disturbing the chunkwood sub-base.

SUMMARY:

After initial construction, the roadbed had adequate moisture to retain template under repeated loads even though some rutting and deformation occurred in the chunkwood sections due to compaction under heavy traffic. As the summer progressed and the water table receded, the continued heavy traffic, (80,000 lb. GVW chip vans) pounded the roadbed into a dusty trough. In the chunkwood sections the pumice surface course had dried out and had lost its cohesiveness and support. further rutting occurred, and the chunkwood layer was exposed as the trucks plowed into the treated areas. Conditions were compounded by improper user maintenance in attempting to backblade the road surface with a dozer. Some of these problems could have been mitigated by trucks reducing speeds when entering chunkwood areas, "off-tracking" or splitting the wheel tracks to heal the rutting, and proper maintenance.

Observations during the following summer, indicated that the chunkwood segments held up well to the previous spring haul and even though the chunkwood was exposed the repeated traffic had compacted and stabilized the mass. The moisture was still adequate at the time of observation but speculation was that it would deteriorate and the roadbed dried out.

High chunkwood production cost was mentioned, $60. per cubic yard. This figures out to a production rate of the chunker at 2 tons of chunks per hour compared to a rate of 26 tons per hour under ideal conditions. The extra cost was due to trying to pull material out of a settled pile with the chunker loader, which has limited reach and lifting capacity. Dry material does cause some heating problems with the cutter blades. Green material brought to the machine with a forwarder is the most productive method of producing chunkwood.

RECOMMENDATIONS:

The high cost of producing the chunks could have been alleviated by using a forwarder to move the material to the chunker. Using green material in the 6 to 8 inch class in a "hot deck" operation could reduce the cost of producing chunks to about $2.50/cu yd.

A "pumice type " soil may not have enough binder or cohesiveness to adequately remain in the void area of the chunkwood fill.

Seasoning of the road may be necessary before operations occur on a heavy haul road.

SITE: KISATCHIE NF, Louisiana

DATE: July 20, 1988

SITE DESCRIPTION:

These roads are considered "fair weather" roads, (only used during fair weather). The chunkwood was applied to the surface to determine its durability under logging traffic.

DESIGN DESCRIPTION:

Chunks were applied on three roads. On one road only the first 100 feet had 12 inches of chunkwood applied to the surface. The remainder of this road has pit run rock or native surfacing. The second road which is about 1/2 mile long had the first 50 feet and the last 1/4 mile covered with 12 inches of chunks. The last road had 6 inches of chunks placed under 3 inches of pit run rock.

SUMMARY:

About 1 MMBF of timber was hauled over the first two test roads. The weather was not a factor during the haul periods not much was determined from the test. Chunkwood was determined to perform adequately under these conditions.

RECOMMENDATIONS:

None.

SITE: Ft Nelson, B.C., Canada

DATE: August 1990

SITE DESCRIPTION:

The typical practice for building logging roads in this part of the country is that the vegetative mat and mineral soil is removed and trucks typically operate over the heavy clay subsoil. This works fine for the winter months and during the dry parts of the year. However, when the rainy season occurs, the road becomes unusable and even when the surface dries out, trucks have to be towed through some heavy clay pockets or"Gumbo" sections, as the clay pockets seldom dry out.

DESIGN DESCRIPTION:

Approximately 2 km, of a 4 km access road, was covered with a average depth of from 4 to 6 inches of aspen chunkwood. In the locations where heavy clay pockets were present the chunkwood application increased to a depth of 18 inches. Some chunkwood was stockpiled so that it could be added if additional soil stabilization was necessary. Once the chunkwood was in place and graded normal truck traffic resumed.

SUMMARY:

The chunkwood road worked well in the "gumbo areas" immediately after the chunkwood application. Initially the sections of the road with the thin covering of chunkwood did nothing for the road but when the weather changed, and the area got some rain mixed with snow ,the road got some better evaluation. Over the portion of the road that had chunkwood applied to the surface, the hauling continued but where the chunkwood ended, all operations ceased even to 4 wheel drive vehicles. The sections that were covered with 4 to 6 inches of chunkwood carried traffic even though the chunks migrated down below the road bed surface about 6 inches. The company that built the test chunkwood road is sold on the concept and are negotiating for having more demonstration roads built. We talked with the B.C. Forest Service about typical applications and interest was high about potential chunkwood use. There is a lot of sesimic exploration in that area and many potential applications exist on seismic access corridors. Concern exists, however, about leachates from the chunkwood and how it would affect the nearby ground water. The chunkwood production rate at the Ft Nelson site was about 110 cubic yards an hour when the machine was set up at a landing and material brought to it with a skidder.

RECOMMENDATIONS:

The chunkwood worked well as a material to stabilize clay pockets in the road beds. Material should be stockpiled so additional chunkwood can be added if some of the initial material get worked down further into the clay.

The application rate of 4 inches was adequate to support truck traffic on the clay sub-base even though the chunkwood material migrated down into the roadbed. However to carry loads on finer clays or weaker soils an application rate of 6 inches on the surface would be more appropriate.

SITE: Quest Forest Products Ltd., Quesnel, B.C., Canada

DATE: August 1990

SITE DESCRIPTION:

Chunkwood was used as a fill to make heavy clay pockets passable on the secondary haul roads. Typically the clay pockets were filled with gravel and after a few truck passes more gravel fill needed to be added or crawlers used to pull the loaded trucks through. Chunkwood stabilized the clay pockets in the roads, and trucks no longer had to be towed through the problem areas.

DESIGN DESCRIPTION:

No particular design was applied at this location. The clay pocket treated was large and much of the material was displaced out of the road bed. About 10 dump truck loads were placed over the problem section and a dump truck loaded with gravel was driven over the chunkwood. Logging traffic resumed over the section.

SUMMARY:

Chunkwood stabilized the clay pockets present in the secondary haul roads. The clay moved up to the surface through the chunks but the chunkwood material seemed to only move down 5 or 6 inches below the road surface. A compacted layer occured at that level. Additional chunkwood material should be located at those locations to be added as necessary. Unmerchantable material is usually available on most logging sites and can be used as the fill material for stabilization of the clay pockets. Gravel when used, has to be hauled to the site and normally be continually added to the pocket to carry the logging traffic.

RECOMMENDATIONS:

Chunkwood performed well for this application but personnel at this location thought that the machine configuration should consist of a self propelled unit mounted on tracks with a knuckle boom loader that would reach out 30 feet from the machine so that unmerchantable material could be reached and utilized for repair of the haul road from that road.

SITE: Section 16-T69-R22 Minn. State Permit #0002V Ray, Minnesota

DATE: September 1987

SITE DESCRIPTION:

The road was located in a low wet boggy area where small areas of standing water were present during the wet seasons of the year.

DESIGN DESCRIPTION:

This road was 400 feet long. The width varied from 14 to 20 feet. The depth of chunks varied from 1 to 2 feet. The only preparation done to the road "right of way" was; the trees were cut close to the ground, the small brush trampled with with the feller-buncher and the windfall trees removed. Approximately 270 cubic yards, (or 36 cords), of chunks were used.

SUMMARY:

The road worked well. The loader truck was driven over the road twice to slightly compact the chunks before hauling started. 25 semi-truck loads, (10 cords per load), were hauled out over the chunkwood road. The road stayed in good shape for the duration of the hauling with no maintenance necessary.

Starting the road initially was difficult because a ditch had to be crossed before the road "right of way" material could be utilized. The chunkwood required to cross the ditch was processed elsewhere and then hauled to the road site. Due to the small tires on the chunker and the low ground clearance the chunker could not be moved over the ditch to the wood and the wood couldn't be moved across the ditch to the chunker.

Estimated costs are:

Stumpage -----------------	$ 4.60 per cord
Felling ------------------	$ 5.00 per cord
Limbing ------------------	$ 3.00 per cord
Skidding -----------------	$ 5.00 per cord
Chunking -----------------	$ 8.00 per cord
Spreading ----------------	$ 5.00 per cord
TOTAL	$30.60 per cord

Projected costs:

$ 30.60 / 7.6 yards per cord = $ 4.03 per cubic yard

These figures are estimates and will vary greatly as to the actual out-of-pocket money for the contractor. Limbing would not be necessary for most of the 8 to 12 inch diameter material for the MTDC Chunker.

RECOMMENDATIONS:

A chunker built on all-terrain tracks that could be transported by lowboy from job to job would be desirable.

SITE: Koochiching County permit #K9-180 Ray, Minnesota

DATE: October 1989

SITE DESCRIPTION:

The soil in this area was a fine grained soil high in clay content. Traction is very limited on this soil when wet.

DESIGN DESCRIPTION:

The length of this road was 500 feet long. Width was maintained at 14 feet. Depth of chunkwood initially was 6-12 inches and later increased to 12-18 inches. Approximately 50 cords of chunkwood were used.

The road bed was prepared with a small, (450 John Deere), bulldozer. All stumps, windfalls, rocks, trees, and brush were removed before chunks were applied.

SUMMARY:

Because the road bed seemed fairly firm at the time of construction only 6 inches of chunkwood was applied on the road bed surface. As it became evident that the thickness was not enough to support truck traffic an additional 6 inches of chunkwood was applied to the first 200 feet of the road. Hauling of 10 cord loads of pulpwood started and the first the section of road with the 12 inch depth of chunkwood held up fairly well under the loads. However the later section of the road with only 6 inches of chunkwood did not perform satisfactorily and the trucks had to be towed through that section with a crawler. Another 6 inches of chunkwood was added to the last part of the road which then corrected the problem.

RECOMMENDATIONS:

On fine grained soils with a high clay content at least 12 inches of chunkwood should be used.

SITE: Ft Nelson, B.C., Canada

DATE: April 1991

SITE DESCRIPTION:

The typical practice for building logging roads has been discussed in the previous test conducted at the Fort Nelson area. This section of road was was constructed to evaluate the application of chunkwood as a method of extending the aspen hauling season by allowing earlier entry of trucks into a harvested area during spring.

DESIGN DESCRIPTION:

Approximately a 2 km access road, was covered with a layer of aspen chunkwood. A "sheeps-foot packer" was used to work the chunks into the subgrade 4 to 6 inches and the top grade was then bladed smooth. In the locations where heavy clay pockets were present several layers of chunkwood were applied and worked into the subgrade. Once the chunkwood was in place and graded normal truck traffic resumed.

SUMMARY:

The chunkwood road worked well under the wet spring conditions. The chunkwood carried the load from hauling traffic and did not appear to migrate deeper into the subgrade. This process made the road surface more trafficable and a smoother ride was obtained.

RECOMMENDATIONS:

The chunkwood worked well as a material to extend the haul season, in early spring, over the heavy clay road bed surface. Material should be stockpiled so additional chunkwood can be added if some of the initial material get worked down further into the clay.

The application rate of 4 inches was adequate to support truck traffic on the clay sub-base even though the chunkwood material migrated down into the roadbed. However to carry loads on finer clays or weaker soils an application rate of 6 inches on the surface would be more appropiate.

SITE: Juneau Creek Chunkwood Road-#1010500, Coopers Landing, Alaska

DATE: Oct. 1991 - Aug. 1992

SITE DESCRIPTION:
The majority of the site was course loamy soil with some silt loam on about 15 percent of the site. White Birch, White Spruce were the predominate trees with blue joint grass present on much of the area. The terrain was mostly level with some rolling hills and side slopes up to a 10 percent grade. The precipitation for the area averages 20 to 40 inches annually. Average annual temperature ranges from 28 to 34 degrees.

DESIGN DESCRIPTION:
The chunkwood road was 1.4 miles in length and approximately 85% of the road utilized some type of chunkwood application as described in the Design Section below. The road had a contoured alignment with rolling grades ranging from 1-11%. Compaction of embankment was not specified, but was accomplished by operating construction equipment over the full width of the road section. Plate load testing was not conducted.

Various road profiles were used on the test road including some areas that included a geotextile fabric. Areas of high moisture content were covered with deeper sections of chunkwood. The various profiles used are:

- -Chunkwood only over undisturbed soil profile.
- -Chunkwood only on AMOCO 2006 geotextile fabric over undisturbed soil profile.
- -Chunkwood only on log corduroy.
- -Chunkwood only on AMOCO 2006 geotextile fabric over log corduroy.
- -Pit run gravel over chunkwood.
- -Chunkwood admixed with native road construction materials.

SUMMARY:
The chunkwood road worked well under wet spring conditions. The chunkwood allowed entry into the area before traffic would normally have access to the area. In some areas bed rock is located close to the surface and any moisture that drains from the area above has to pass under the road subgrade or thru the chunkwood embankment. The area that contained the 11% adverse grade with approximately 12 inches of chunkwood overlay had to have a pit run gravel cap of 4 inches applied to enable logging trucks to have adequate traction to pull the grade. Chunkwood embankment seemed to provide a better structure after it had been used for some time and broken down into large chips that were inter-locked and compacted. Some lateral displacement of chunkwood embankment was observed possibly due to a combination of road subgrade, alignment, grade, chunkwood embankment depth, and chunkwood/snow mixture placement during periods of heavy snowfall. When the chunkwood was mixed in with snow, the interlocking between chunkwood particles did not take place and mobility on grades in the recently placed chunkwood topgrade was a problem. The snow acted as a lubricant and allowed the chunkwood particles to rotate with little resistance.

RECOMMENDATIONS:
The chunkwood worked well as a material to allow traffic to enter the area earlier in the season without higher cost construction alternatives that would use gravel subgrades which would be hauled in from adjacent areas.

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Additional culverts or drainage would need to be added to s
road to provide adequate drainage.

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The chunkwood worked well as a material to allow construction traffic to enter the area earlier in the season without higher construction designs that would use gravel subgrades that would be hauled in from adjacent areas. Additional culverts or drainage would need to be added to parts of the road to provide adequate drainage. When designing chunkwood embankment sections subsurface soil investigations are recommended such as vane shear tests in cohesive soil and dynamic cone penetrometer testing, correlations may be used to determine chunkwood embankment depth. An allowance of 10-20% compression should also be allowed in calculating depth of chunkwood embankment. It appears that problems with truck traction began around 7% adverse grade on chunkwood only sections. In general low inflation tire pressures in combination with wide tires may be a good application on chunkwood roads. If chunkwood is placed on the roadbed surface during the winter months care should be taken not to allow it to mix with the snow during placement so the wood fibers have a chance to overlap and interlock. This will aid in trafficability during construction and reduce lateral movement of chunkwood off the road bed surface.

Chunkwood technology has it's application, but if it is to progress existing prototype chunkwood machine should be replaced by a more advanced machine incorporating changes in machine technology as recommended by it's users.

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